PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P3S2004351	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/JP2005/000949	International filing date *(day/month/year)* 19.01.2005	Priority date *(day/month/year)* 19.01.2004
International Patent Classification (IPC) or national classification and IPC INV. F01L13/00		
Applicant TOYOTA JIDOSHA KABUSHIKI KAISHA et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 8 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 6 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the report
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
14.10.2005	09.06.2006
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Clot, P Telephone No. +49 89 2399-2724

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/JP2005/000949

Box No. I Basis of the report

1. With regard to the **language**, this report is based on

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3(a) and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4(a))
   - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a))

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages	
1-57	as originally filed
Claims, Numbers	
1-16	received on 14.10.2005 with letter of 14.10.2005
Drawings, Sheets	
1/27-27/27	as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-16
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-16
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-16
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:
D1: EP-A-1 143 119
D2: US-A-5 267 536
D3: US-A-6 216 557
D4: EP-A-0 281 990
D5: US-A-3 490 423

1) The document D1 corresponds to the JP publication 2001-263015 cited in the description of the present application and is regarded as being the closest prior art to the subject-matter of the independent claim 1, 13 or 15.

2) Novelty claims 1, 13, 15

2.1 claim 1
D1 shows (the references in parentheses applying to this document):
a variable valve actuation mechanism for an internal combustion engine, the mechanism comprising an intervening drive mechanism (120), a control shaft (132), and an actuator (100), wherein the intervening drive mechanism transmits drive force from a cam provided in a cylinder head of the engine to a valve, the control shaft is engaged with a valve actuation controller provided in the intervening drive mechanism and moves the valve actuation controller 128 in an axial direction to adjust the valve actuation, and the actuator moves the control shaft in an axial direction to adjust the valve actuation,
the internal combustion engine having a plurality of cylinders (see D1, fig.4), the intervening drive mechanism being one of a plurality of intervening drive mechanisms each provided for one of the cylinders,
the control shaft having an engaging portion (see Fig.16A, pin 132a) that is engaged with the valve actuation controller,
the control shaft being common to all the intervening drive mechanisms, the engaging portion being one of a plurality of engaging portions.

The subject-matter of claim 1 differs from this known mechanism by the remaining characterising features, indicating that

the engaging portion is made of a high strength material, wherein a remaining portion of the control shaft other than the engaging portion is made of a material that is different from the material of the engaging portion, such that the thermal expansion coefficient of the entire control shaft is made closer to the thermal expansion coefficient of the cylinder head,
and the remaining portion is one of a plurality of remaining portions, the engaging portion and the remaining portion being located alternately.

Document D2 discloses push rods formed of an aluminium alloy with an iron contacting chip at the rod end engaging a rocker arm. Push rods of this kind are also disclosed in D3.
D2 or D3 disclose a push rod made of two different materials, not a control shaft common for all cylinders in a mechanism having the features of claim 1.

2.2 claim 13
D1 shows (the references in parentheses applying to this document):
a variable valve actuation mechanism for an internal combustion engine having a plurality of cylinders, the mechanism comprising intervening drive mechanisms (120) each provided for one of the cylinders, a control shaft (132), and an actuator (100), wherein each intervening drive mechanism transmits drive force from one of cams provided in a cylinder head of the engine to a valve, the control shaft is engaged with a valve actuation controller provided in the intervening drive mechanism and moves the valve actuation controllers 128 in an axial direction to adjust the valve actuation, and the actuator moves the control shaft in an axial direction to adjust the valve actuation, the valve clearance of each valve being adjusted by a lash adjuster (13b).

The subject-matter of claim 13 differs from this known mechanism by the remaining characterising features, indicating that
the leak down property of the lash adjusters are set different among the cylinders to suppress variation of the valve actuation among the cylinders due to a difference in the thermal expansion coefficient between the control shaft and the cylinder head in

relation to the thermal expansion of each intervening drive mechanism.

The subject-matter of claim 13 is therefore new (Article 33(2) PCT).

2.3 claim 15:
D1 shows (the references in parentheses applying to this document):
a variable valve actuation mechanism for an internal combustion engine having a plurality of cylinders, comprising intervening drive mechanisms (120) each provided for one of the cylinders, a control shaft (132), and an actuator (100), wherein each intervening drive mechanism transmits drive force from one of cams provided in a cylinder head of the engine to a valve, the control shaft is engaged with a valve actuation controller provided in the intervening drive mechanism and moves the valve actuation controllers 128 in an axial direction to adjust the valve actuation, and the actuator moves the control shaft in an axial direction to adjust the valve actuation, the valve clearance of each valve being adjusted by a lash adjuster (13b).

The subject-matter of claim 15 differs from this known mechanism by the remaining characterising features, indicating that the pressure of oil supplied to the lash adjusters is independently adjusted for each cylinder according to the temperature of the internal combustion engine to suppress variation of the valve actuation among the cylinders due to a difference in the thermal expansion coefficient between the control shaft and the cylinder head in relation to the thermal expansion of each intervening drive mechanism.

2.4 The subject-matter of claims 1, 13 and 15 is therefore new (Article 33(2) PCT).

3) Inventive activity
The problem to be solved by the present invention may be regarded as the problem of differential thermal expansion between the control shaft, made for functional reasons of a high-strength material such as an iron based material, and the light alloy material of the cylinder head, creating undesired relative displacement of the engaging portion of the control shaft, impeding an accurate control of the valve actuation.

The solutions to this problem proposed in claims 1, 13 and 15 of the present application are considered as involving an inventive step (Article 33(3) PCT) for the following reasons:

This problem had as such not been recognized in the specific surrounding of a mechanism according to D1.

3.1 Although problems linked to differential thermal expansion are known from the prior art in the surrounding of valve actuation and solved by adjusting the materials of the elements involved in the valve actuation mechanism, the elements concerned are merely a push rod and its end contacting a rocker arm as illustrated in D2 (see D2, column 13, lines 3-68) or D3 (see D3, Fig.1 and column 6, lines 6-13); the rod is thus provided at a single location, which is its rocker arm contacting end, with a iron based material different from the aluminium alloy material of the remaining rod.

There is no hint to providing a control shaft common for a plurality of cylinders such as known from D1 with a plurality of alternating locations made of different materials and to arrive without the benefit of hindsight to the subject-matter of claim 1.

3.2 While it is known to take account of the differences in leak down flows out of the pressure chamber of a hydraulic lash adjuster according to the thermal loading, the oil temperature having a direct influence onto the oil viscosity and thus onto leak down flow, the known solutions are intended for keeping the leakage flow substantially constant.
A solution illustrated in D4 consists in having the leakage clearance adjusted as a function of the temperature loading, by appropriate use in the lash adjuster of materials having different thermal expansion coefficients, so that the leak down flow and thus the behaviour of the lash adjuster is kept accurate throughout the range of thermal loading.
The application of this teaching to the lash adjusters of D1 would not permit to compensate for variations due to differences in thermal expansion of the various elements and in particular of the common control shaft of the variable valve actuation mechanism, as set out in claim 13.

3.3 The subject-matter of claim 15 differs from the disclosure of D1 in that the pressure of oil supplied to the lash adjusters is independently adjusted for each cylinder according to the temperature of the internal combustion engine to suppress variation of the valve actuation among the cylinders due to a difference in the thermal expansion coefficient between the control shaft and the cylinder head in relation to the thermal expansion coefficient of each intervening drive mechanism.

These features solve the same problem as for claim 1 and claim 13.

It is known to include a pressure adjustment in relation with a given lash adjuster in order to permit increase or decrease of the pressure supplied to this lash adjuster. This is in particular used for valve deactivation such as illustrated in D5.
This adjustment of pressure is however not intended to be performed individually for compensating a variation of valve actuation such a variation due in D1 to the relative expansions of various elements involved in the valve actuation mechanism under thermal load.

4) Claims 2-12, 14 and 16 are dependent on claim 1, claim 13 and claim 15 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

5) The two-part form (Rule 6.3(b)(ii) PCT) of independent claims 1, 13 and 15 should take account of the fact that D1 discloses not only the features of the preamble of these claims, but also some characterising features as indicated under items 2.1, 2.2, 2.3 hereabove.

Amended set of Claims

1. A variable valve actuation mechanism for an internal combustion engine, the mechanism comprising an intervening drive mechanism, a control shaft, and an actuator, wherein the intervening drive mechanism transmits drive force from a cam provided in a cylinder head of the engine to a valve, the control shaft is engaged with a valve actuation controller provided in the intervening drive mechanism and moves the valve actuation controller in an axial direction to adjust the valve actuation, and the actuator moves the control shaft in an axial direction to adjust the valve actuation, the mechanism being **characterized in that:**

the internal combustion engine has a plurality of cylinders, the intervening drive mechanism is one of a plurality of intervening drive mechanisms each provided for one of the cylinders;

the control shaft has an engaging portion that is engaged with the valve actuation controller and is made of a high strength material, wherein a remaining portion of the control shaft other than the engaging portion is made of a material that is different from the material of the engaging portion, such that the thermal expansion coefficient of the entire control shaft is made closer to the thermal expansion coefficient of the cylinder head;

the control shaft is common to all the intervening drive mechanisms, the engaging portion is one of a plurality of engaging portions and the remaining portion is one of a plurality of remaining portions, the engaging portion and the remaining portion are located alternately.

2. The variable valve actuation mechanism according to claim 1, **characterized in that** the cylinder head is made of a light alloy material, wherein the engaging portion of the control shaft is made of an iron based material, and the remaining portion of the control shaft is made of a light alloy material.

3. The variable valve actuation mechanism according to claim 2, **characterized in that** the light alloy material is an aluminum alloy material or a magnesium alloy material.

4. The variable valve actuation mechanism according to any one of claims 1 to 3, **characterized in that** the remaining portion of the control shaft other than the engaging portion is made of the same material as the material of the cylinder head.

5. The variable valve actuation mechanism according to any one of claims 1 to 3, **characterized in that** the material and the length of the engaging portion and the material and the length of the remaining portion of the control valve other than the engaging portion are set such that the thermal expansion coefficient of the control shaft is substantially the same as the thermal expansion coefficient of the cylinder head.

6. The variable valve actuation mechanism according to any one of claims 1 to 4, **characterized in that:**

the thermal expansion coefficient of the cylinder head is greater than the thermal expansion coefficient of the engaging portion of the control shaft, and the thermal expansion coefficient of the remaining portion of the control shaft other than the engaging portion is greater than the thermal expansion coefficient of the engaging portion;

wherein, between each adjacent pair of the intervening drive mechanisms, the thermal expansion coefficient of the control shaft is set lower than the thermal expansion coefficient of the cylinder head, and wherein the ratio of the length of the remaining portion other than the engaging portion to the length of the engaging portion between each adjacent pair of the intervening drive mechanisms gradually increases as the distance from the actuator to the pair increases.

7. The variable valve actuation mechanism according to claim 6, **characterized in that** the intervening drive mechanisms are arranged substantially at a constant interval, and wherein the length of the remaining portion other than the engaging portion between each adjacent pair of the intervening drive mechanisms increases as the distance from the actuator to the pair increases.

8. The variable valve actuation mechanism according to any one of claims 1 to 7, **characterized in that** the engaging portions of the control shaft and the remaining portions of the control shaft other than the engaging portions are formed separately and are arranged along a common axis while being brought into contact with one another to form the control shaft, and wherein the actuator is provided at one end of the control shaft and urging means is located at the other end of the control shaft to urge the control shaft toward the actuator.

9. The variable valve actuation mechanism according to any one of claims 1 to 5, **characterized in that** the continuity of the material of the remaining portion other than the engaging portion along the axial direction of the control shaft is maintained.

10. The variable valve actuation mechanism according to claim 9, **characterized in that** the remaining portion other than the engaging portion is formed integrally, wherein the engaging portion is buried in and supported by the remaining portion.

11. The variable valve actuation mechanism according to claim 9 or 10, **characterized in that** the engaging portion is engaged with the valve actuation controller by means of a control pin, wherein the engaging portion is provided about the control pin in the control shaft to support the control

pin.

12. The variable valve actuation mechanism according to any one of claims 1 to 11, **characterized in that:**

the valve actuation controller is engaged with a control pin supported by the engaging portion and moves as the control shaft moves in the axial direction, and that the intervening drive mechanism includes:

an input portion, wherein the input portion is engaged with the valve actuation controller by means of a first spline mechanism to receive valve drive force from the cam, and transmits the valve drive force to the valve actuation controller; and

an output portion, wherein the output portion is engaged with the valve actuation controller by means of a second spline mechanism to receive the valve drive force from the valve actuation controller, and transmits the valve drive force to the valve,

wherein the helix angle of the first spline mechanism is different from the helix angle of the second spline mechanism, so that, as the control shaft moves axially, the relative positions of the input portion and the output portion are changed and the valve actuation is adjusted.

13. A variable valve actuation mechanism for an internal combustion engine having a plurality of cylinders, the mechanism comprising intervening drive mechanisms each provided for one of the cylinders, a control shaft, and an actuator, wherein each intervening drive mechanism transmits drive force from one of cams provided in a cylinder head of the engine to a valve, the control shaft is engaged with a valve actuation controller provided in each intervening drive mechanism and moves the valve actuation controllers in an axial direction to adjust the valve actuation, and the actuator moves the control shaft in an axial direction to adjust the valve actuation, the mechanism being **characterized in that:**

the valve clearance of each valve is adjusted by a lash adjuster, wherein the leak down property of the lash adjusters are set different among the cylinders to suppress variation of the valve actuation among the cylinders due to a difference in the thermal expansion coefficient between the control shaft and the cylinder head in relation to the thermal expansion coefficient of each intervening drive mechanism.

14. The variable valve actuation mechanism according to claim 13, **characterized in that**, by creating the difference in the thermal expansion coefficient, the leak down property value of the lash adjuster provided for a cylinder in which the valve actuation value is relatively increased due to a high temperature is set greater than the leak down property value of a cylinder in which the valve actuation value is relatively decreased due to a high temperature.

15. A variable valve actuation mechanism for an internal combustion engine having a plurality of cylinders, comprising intervening drive mechanisms each provided for one of the cylinders, a control shaft, and an actuator, wherein each intervening drive mechanism transmits drive force from one of cams provided in a cylinder head of the engine to a valve, the control shaft is engaged with a valve actuation controller provided in each intervening drive mechanism and moves the valve actuation controllers in an axial direction to adjust the valve actuation, and the actuator moves the control shaft in an axial direction to adjust the valve actuation, the variable valve actuation mechanism being **characterized in that:**

the valve clearance of each valve is adjusted by a lash adjuster, wherein the pressure of oil supplied to the lash adjusters independently adjusted for each cylinder according to the temperature of the internal combustion engine to suppress variation of the valve actuation among the cylinders due to a difference in the thermal expansion coefficient

between the control shaft and the cylinder head in relation to the thermal expansion coefficient of each intervening drive mechanism.

16. The variable valve actuation mechanism according to claim 15, **characterized in that**, by creating the difference in the thermal expansion coefficient, the pressure of oil supplied to the lash adjuster provided for a cylinder in which the valve actuation value is relatively increased due to a high temperature is set smaller than the pressure of oil supplied to a cylinder in which the valve actuation value is relatively decreased due to a high temperature.